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Bird community structure and seasonal dynamics in a forest ecosystem of West Bengal, India

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Abstract Several ornithological studies have been conducted across West Bengal recently, yet the forest habitats of the Matha region in Purulia district remain largely unexplored. The present study aimed to assess the diversity, abundance, and seasonal variation of bird species in this understudied forest landscape. Findings revealed that bird species richness peaked during the post-monsoon season (October–December), coinciding with increased food availability due to higher insect populations and agricultural activity, as well as the presence of juvenile birds following the breeding season. Despite the arrival of winter migrants, the limited number of water bodies resulted in lower waterbird abundance during winter. The forest's proximity to croplands favoured granivorous species, while omnivorous birds were the most dominant feeding guild, reflecting diverse resource utilization. Rock Pigeon, Eurasian Collared Dove, and Spotted Dove emerged as ecologically significant species based on abundance, frequency, and Important Value Index metrics. Asian Palm Swift and House Crow were also frequently observed. Columbidae was the most species-rich family, followed by Cuculidae and Sturnidae. The seasonal shifts in avian community composition highlight the dynamic interplay between habitat characteristics, food availability, and climatic factors. The study underscores the importance of continued ecological monitoring and conservation planning in the region.

Keywords: avian diversity, seasonal variation, feeding guilds, Matha Forest, forest habitat

Összefoglalás Az elmúlt években számos madártani vizsgálatot végeztek Nyugat-Bengálban, de a Purulia körzetben található Matha régió erdei élőhelyei még mindig nagyrészt feltáratlanok. Jelen tanulmány célja a madárfajok diverzitásának, abundanciájának és szezonális változásának felmérése volt ezen az alulvizsgált erdős területen. Az eredmények azt mutatták, hogy a madárfajok gazdagsága a monszun utáni időszakban (október-december) tetőzik, ami egybeesik a nagyobb rovarpopulációk és a mezőgazdasági tevékenység miatt megnövekedett táplálék elérhetőségével, valamint a költési időszakot követő fiatal madarak jelenlétével. A téli vonulók érkezése ellenére a korlátozott számú víztestek miatt a téli időszakban a vízimadarak száma alacsonyabb volt. Az erdőnek a szántóföldekhez való közelsége kedvezett a magevő fajoknak, míg a mindenevők voltak a legdominánsabbak, ami a változatos erőforrás-felhasználást tükrözi. A szirti galamb, a balkáni gerle és a gyöngyösnyakú gerle ökológiailag jelentős fajokként jelentek meg a tömegesség, gyakoriság, és a dominancia mérőszámai alapján. Az ázsiai pálmasarlósfecske és a házi varjú is gyakran megfigyelhető volt. A Columbidae volt a legfajgazdagabb család, amelyet a Cuculidae és a Sturnidae követett. A madárközösség összetételének szezonális változása rávilágít az élőhelyi jellemzők, a táplálék elérhetősége és az éghajlati tényezők közötti dinamikus kölcsönhatásra. A tanulmány hangsúlyozza a folyamatos ökológiai megfigyelés és természetvédelmi tervezés fontosságát a régióban.

Kulcsszavak: madarak diverzitása, évszakos változatosság, táplálkozási guild-ok, Matha erdő, erdei élőhely

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Introduction

One of the most important organisms on Earth are birds, and their wide variety contributes to the beauty and richness of life. Birds plays an essential role in ecosystem services particularly in pollination, seed dissemination, pest management, nutrient cycling, and others (Whelan *et al.* 2008, Sekercioglu 2012). Birds can be present in different types of habitats including water bodies (Kumar *et al.* 2006, Kumar & Gupta 2013), forests (Aich & Mukhopadhyay 2008, Roy *et al.* 2011, Chatterjee *et al.* 2013), and agricultural fields, and are considered as bioindicators since they are essential from the perspective of ecological monitoring (Roy *et al.* 2012, Dubey *et al.* 2015, Mukhopadhyay & Mazumdar 2019, Kamala *et al.* 2021). Sometimes, population patterns of birds in an area indicate natural stressors like drought (Blake *et al.* 1994) or introduction of alien species by human intervention and urbanization (Savidge 1984, O'Connell *et al.* 2000).

Thus, it is essential to understand the community structure and diversity of bird communities to determine the significance of different types of landscapes for avian conservation (Kattan & Franco 2004). Forests bring a huge number of avifauna assemblages because of the preferable habitats, particularly those birds that are directly linked with vegetation, and for the majority, trees are an essential part of their life cycle. Globally, 75% of all bird species are adapted to live in forest habitats (BirdLife International 2018).

Numerous ornithological studies on diversity, and its status, have been carried out in West Bengal. However, forest areas have been less explored regarding avian diversity and status. Some studies have been conducted in this context in several forest habitats, for example in Patlakhawa Protected Forest, Coochbehar (Chatterjee *et al.* 2013), Chilkigarh, Jhargram (Das *et al.* 2022) and Chintamoni Kar Bird Sanctuary (Sen *et al.* 2023).

Previous works have been done on avian diversity in the Purulia town (Mahato *et al.* 2021), Baghmundi (Samanta *et al.* 2023). Although documentation of avian diversity in the forest habitat of Matha region of Purulia, West Bengal is scarce, therefore, the present study is designed to document the diversity of birds along with the seasonal variation in the Matha Forest of the Purulia district of West Bengal is of much importance.

Materials and Methods

Study area

The current study on avifaunal diversity has been conducted in the forest habitats of Matha Forest (23°11' N and 86°09' E) of Purulia district in West Bengal, India from April 2023 to March 2024 *(Figure 1)*. The landscape consists of vast stretches of dry deciduous forests with rough mountains. The tropical climate of the study area holds a mean annual rainfall of about 1,100–1,500 mm. The temperature ranges from 45 °C (in summer) to 10 °C (in winter) and relative humidity lies between 80% in monsoon and 30% in winter season.

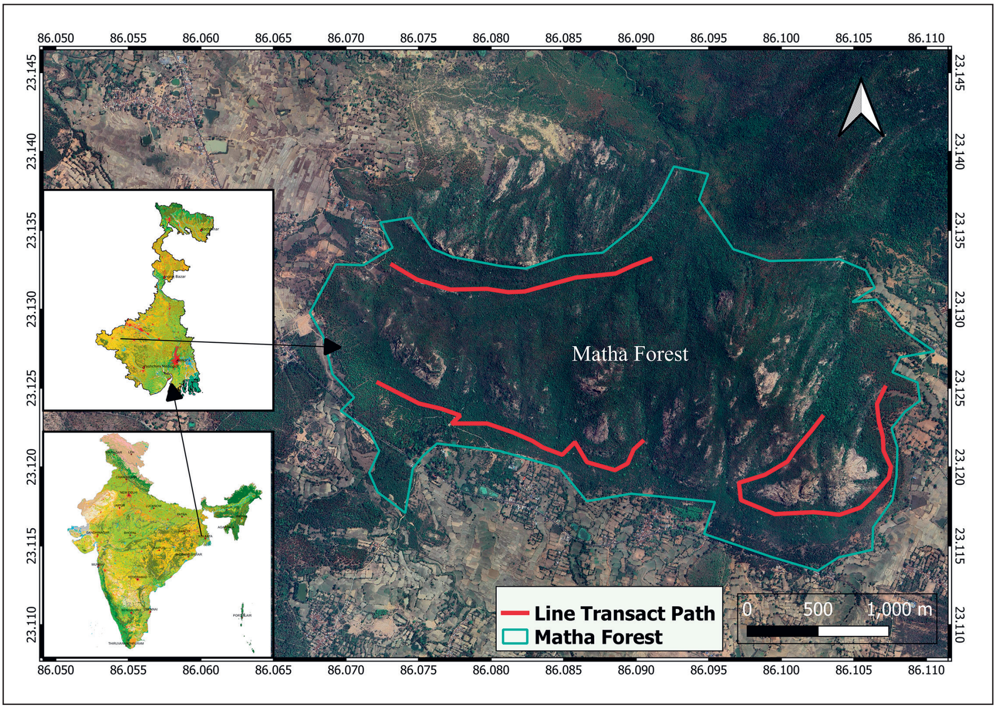

Figure 1. Map showing the different trails followed across the Matha Forest Transact Lines with detailed imagery of the forest in Purulia

1. ábra A Matha erdőben bejárt transzektvonalak különböző ösvényeit bemutató térkép a puruliai erdő részletes képi ábrázolásával

Data collection

The bird counts have been carried out on seasonal basis, i.e. summer (April to June), monsoon (July to September), post-monsoon (October to December) and winter (January to March) by field visits and sampling. In each season, we have selected 8 days in particular for this study. A total of three transects were laid that covered most of the study area. To assess bird diversity using the line transect method, three ecologically varied trails were selected within the Matha Forest. We have selected these three paths along with the GPS data collected during the study. The first trail is located near the village boundary, representing a disturbed habitat influenced by human activities such as grazing, wood collection, and agriculture. The second trail is situated at a higher elevation, where human interference is minimal, offering a relatively undisturbed and natural forest environment ideal for observing birds in their native habitat. The third trail runs along the hilly perimeter of the forest, designed to encircle the region and cover a broad range of habitat types and elevation gradients. Together, these trails provide a comprehensive representation of the forest's ecological variation, allowing for comparative analysis of bird species richness and abundance across different disturbance levels and habitat conditions.

Sampling was carried out in the early morning time (5.30 a.m. – 9.00 a.m.) and evening time (3.30 p.m. – 5.30 p.m.) by using Nikon Binoculars (12×50) and Sony α 6400 cameras.

During the surveys we have identified three different trails in order to count the birds by line transect methods. The different birds were identified and recorded by using the books of Ali (2002), Grimmett *et al*. (2011) and with the help of indigenous people in that area. Sometimes, the calls of the birds have been recorded for identification purposes (Hossain & Aditya 2016). Rainy conditions were avoided during the surveys. All the birds were categorized based on their taxonomic classification and feeding habits like omnivorous, carnivorous, insectivorous, invertivorous, molluscivorous, herbivorous, granivorous, nectarivorous and frugivorous (Willis 1979, Ali 2002).

Richness evaluation

Bird diversity was assessed using species richness and total abundance, based on the number of species recorded at each site. A species accumulation curve was plotted to evaluate whether the sampled bird species accurately represented the overall bird community. Additionally, individual-based rarefaction curves were employed to compare species richness across different habitats and seasons.

Bird assemblage and statistical analysis

To estimate daily species density, the density per day (D) was calculated by dividing the total number of individuals of each species recorded across all survey days by the total number of days on which surveys were conducted.

$$Density\ per\ Day(D) = \frac{Number\ of\ Individual\ of\ the\ species\ in\ all\ the\ day}{Number\ of\ days\ surveyed}$$

Relative Density (RD) was calculated as the proportion of the density of a particular species to the total density of all recorded species, multiplied by 100. This metric provides a percentage representation of how dominant or common a species is within the overall bird community during the survey period.

$$Relative\ Density\ (RD) = \frac{Density\ of\ the\ species}{Total\ density\ of\ all\ species} x100$$

Frequency (F%) was calculated by dividing the number of days on which a particular species was observed by the total number of survey days and then multiplying the result by 100. This measure indicates how consistently a species was encountered across the study period, reflecting its temporal occurrence within the surveyed habitat.

$$Frequency(F\%) = \frac{Number\ of\ days\ in\ which\ species\ occurred}{Total\ number\ of\ days\ studied} x100$$

Relative Frequency (RF) was calculated by dividing the frequency of occurrence of a given species by the sum of frequencies of all recorded species and multiplying the result by 100. This index provides a percentage-based measure of the relative temporal occurrence of each species within the overall bird community, offering insights into how regularly a species appears in relation to others during the study period.

$$Relative\ frequency(RF) = \frac{Frequency\ of\ the\ species}{Total\ frequency\ of\ all\ the\ species} x100$$

Abundance (A) was calculated by dividing the total number of individuals of a species recorded across all sampling days by the number of days on which that species was observed. This metric reflects the average number of individuals present per day of occurrence, providing insight into the species' population density when present.

$$Abundance(A) = \frac{Total\ number\ of\ individuals\ of\ the\ species\ in\ all\ the\ sampling\ days}{Number\ of\ sampling\ days\ in\ which\ species\ occurred}$$

Relative Abundance (RA) was calculated by dividing the abundance of a given species by the total abundance of all recorded species, then multiplying by 100. This percentage represents the proportion of individuals of each species relative to the entire bird community, highlighting the dominance or commonness of species within the study area.

$$Relative\ Abundance(RA) = \frac{Abundance\ of\ the\ species}{Total\ abundance\ of\ all\ the\ species} x100$$

The Importance Value Index (IVI) was calculated by summing the Relative Density, Relative Frequency, and Relative Abundance of each species. This composite index provides an integrated measure of a species' overall ecological significance within the bird community, reflecting its abundance, distribution, and dominance in the study area.

$$Importance\ Value\ Index(IVI) = Relative\ Density + Relative\ frequency + Relative\ Abundance$$

Shannon's diversity index (H) refers to the quantitative measure that reflects how many different species are present in a community (species richness) and how evenly the individuals are distributed among those species (species evenness). Here *pi* is the proportion (n/N) of individuals of a particular species found (n) divided by the total number of individuals recorded (N), ln is the natural log, and ∑ is the sum of the calculations.

$$Shannon's\ diversity\ index(H): H = \sum pi \log(\ln) pi$$

Simpson's diversity index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species. Here n is the total number of birds of a particular species and N is the total number of birds of all species.

$$Simpson\ diversity\ index(D): D = 1 - \sum n(n-1)/N\,(N-1)$$

The evenness index (J) is a metric used in ecology to quantify how evenly distributed individuals are among the different species in a community. Here H is the Shannon's diversity index, and H_{max} is the natural log of the total number of species.

$$Evenness\ Index\ (J): J = H/Hmax$$

The Berger–Parker index measures the dominance of the single most abundant species relative to the total abundance of all species. Here, DBP is the Berger–Parker index and Nmax is the number of individuals in most abundant species whereas N is the total number of individuals in all species combined.

$$DBP = Nmax/N$$

The Margalef index is the measure of species richness to estimate biodiversity. D_{MG} is the Margalef index and S is the number of species in the sample, N is the total number of individuals in the sample, ln is the natural logarithm.

$$DMG = (S-1)/lnN$$

The Menhinick index is also used to measure species richness allowing the comparisons between samples of different sizes. D_{MN} is denoted as the Menhinick index and Sis the total number of species in the sample, N is the total number of individuals in the sample.

$$DMN = S/\sqrt{N}$$

Species abundance refers to the sum of individuals from a given species within a given area. Here Sn is the number of the bird in the reference species and N is the total number of birds.

$$Species\ Abundance = Sn/N$$

Four similarity indices were calculated to estimate shared species richness between different seasons. These included qualitative similarity estimates using the Bray–Curtis similarity or distance index, Euclidian distance, Jaccard index, and Morisita index.

The non-parametric multidimensional scale (NMDS) test was performed to check the significant variation of bird community among the seasons. One-way ANOVA test was run to check the variation of birds' richness. The data analysis and plots were performed by the PAST 4.17 and R 4.5.1.

Results

Species diversity

We found a total of 2,786 individuals of 75 bird species classified into 49 genera and 42 families in the Matha Forest according to the followed transects in four different seasons for the span of a year. Seasonal total bird count differed as the post-monsoon count was the highest (997) and the monsoon count was the lowest (487). The count in summer and winter is comparatively closer, as in winter 616 and in summer a total of 686 individuals have been observed. However, the species diversity has been strongly varied. The dominant bird family was Columbidae with maximum of six species followed by Cuculidae and Sturnidae comprising five species each. Similarly, there were 24 families of which only one representative species has been observed. In summer, a total of 45 species has been recorded under 28 families dominated by Columbidae, Cuculidae, Ardeidae and Psittacidae comprising three species each and 15 families with only one species. During the monsoon season, a total of 46 species under 31 families has been recorded with highest abundance in Columbidae family having four species and 22 families having only one species. In post-monsoon, a total of 68 species has been recorded belonging to 42 families with highest species count in Columbidae and Sturnidae with four species each and 28 families with a single species. In winter, a total of 44 species has been reported under 28 families with Columbidae and Sturnidae at the dominance with four species each and 17 families with only one species *(Table 1)*.

Table 1. Checklist of the bird species found in Matha Forest with their feeding habits, migratory status and IUCN status. R= Resident, WM= Winter Migrant, LC= Least concern, C= Carnivore, I= Insectivore, G= Granivore, F= Frugivore, O= Omnivore, N= Nectarivore, H= Herbivore, IV= Invertivore, M= Molluscivore

1. táblázat A Matha erdőben észlelt madárfajok listája táplálkozási és vonulási szokásaikkal és IUCN státuszukkal. R= állandó, WM= téli vonuló, LC= legkevésbé veszélyeztetett, C= ragadozó, I= rovarevő, G= magevő, F= gyümölcsevő, O= mindenevő, N= nektárfogyasztó, H= növényevő, IV= féregevő, M= puhatestűeket fogyasztó

Order	Family	Scientific name	Common name	Migratory status	Feeding habit	IUCN status
Anseriformes	Anatidae	*Aythya ferina* (Linnaeus, 1758)	Common Pochard	WM	O	LC
Galliformes	Phasianidae	*Francolinus pondicerianus* (Gmelin, 1789)	Grey Francolin	R	G	LC
Galliformes	Phasianidae	*Pavo cristatus* (Linnaeus, 1758)	Indian Peafowl	R	O	LC
Galliformes	Phasianidae	*Gallus gallus* (Linnaeus, 1758)	Red Jungle Fowl	R	O	LC
Caprimulgiformes	Caprimulgidae	*Caprimulgus asiaticus* (Latham, 1790)	Indian Nightjar	R	I	LC
Caprimulgiformes	Caprimulgidae	*Caprimulgus macrurus* (Horsfield, 1821)	Large-tailed Nightjar	R	I	LC
Apodiformes	Apodidae	*Cypsiurus balasiensis* (J.E. Gray 1829)	Asian Palm Swift	R	I	LC

Order	Family	Scientific name	Common name	Migratory status	Feeding habit	IUCN status
Apodiformes	Apodidae	*Apus affinis* (J.E. Gray, 1830)	Little Swift	R	I	LC
Cuculiformes	Cuculidae	*Centropus sinensis* (Stephens, 1815)	Greater Coucal	R	C	LC
Cuculiformes	Cuculidae	*Eudynamys scolopaceus* (Linnaeus, 1758)	Asian Koel	R	F	LC
Cuculiformes	Cuculidae	*Hierococcyx varius* (Vahl, 1797)	Common Hawk Cuckoo	R	O	LC
Cuculiformes	Cuculidae	*Taccocua leschenaultia* Lesson, 1830	Sirkeer Malkoha	R	O	LC
Cuculiformes	Cuculidae	*Clamator jacobinus* (Boddaert, 1783)	Pied Cuckoo	R	I	LC
Columbiformes	Columbidae	*Columba livia* (Gmelin, 1789)	Rock Pigeon	R	G	LC
Columbiformes	Columbidae	*Spilopelia chinensis* (Scopoli, 1786)	Spotted Dove	R	G	LC
Columbiformes	Columbidae	*Streptopelia decaocto* (Frivaldszky, 1838)	Eurasian Collared Dove	WM	G	LC
Columbiformes	Columbidae	*Streptopelia tranquebarica* (Hermann, 1804)	Red Collared Dove	R	G	LC
Columbiformes	Columbidae	*Treron phoenicoptera* (Latham, 1790)	Yellow-footed Green Pigeon	R	F	LC
Columbiformes	Columbidae	*Spilopelia senegalensis* (Linnaeus, 1766)	Laughing Dove	R	G	LC
Charadriiformes	Charadriidae	*Vanellus malabaricus* (Boddaert, 1783)	Yellow-wattled Lapwing	R	IV	LC
Charadriiformes	Turnicidae	*Turnix suscitator* (Gmelin, 1789)	Barred Buttonquail	R	O	LC
Ciconiiformes	Ciconiidae	*Anastomus oscitans* (Boddaert, 1783)	Asian Openbill	R	M	LC
Pelecaniformes	Ardeidae	*Ardeola grayii* (Sykes, 1832)	Indian Pond Heron	R	C	LC
Pelecaniformes	Ardeidae	*Ardea ibis* (Linnaeus, 1758)	Cattle Egret	R	C	LC
Pelecaniformes	Ardeidae	*Egretta garzetta* (Linnaeus, 1766)	Little Egret	R	C	LC
Pelecaniformes	Threskiornithidae	*Threskiornis melanocephalus* (Latham, 1790)	Black-headed Ibis	WM	I	LC
Accipitriformes	Accipitridae	*Tachyspiza badia* (Gmelin, 1788)	Shikra	R	C	LC
Accipitriformes	Accipitridae	*Milvus migrans* (Boddaert, 1783)	Black Kite	R	C	LC
Accipitriformes	Accipitridae	*Pernis ptilorhynchus* (Temminck, 1822)	Oriental Honey Buzzard	R	C	LC
Strigiformes	Strigidae	*Glaucidium radiatum* (Tickell, 1833)	Jungle Owlet	R	C	LC
Bucerotiformes	Upupidae	*Upupa epops* (Linnaeus, 1758)	Common Hoopoe	R	I	LC
Coraciiformes	Alcedinidae	*Halcyon smyrnensis* (Linnaeus, 1758)	White-throated Kingfisher	R	C	LC

Order	Family	Scientific name	Common name	Migratory status	Feeding habit	IUCN status
Coraciiformes	Coraciidae	*Coracias benghalensis* (Linnaeus, 1758)	Indian Roller	R	C	LC
Coraciiformes	Meropidae	*Merops orientalis* (Linnaeus, 1758)	Green Bee-eater	R	I	LC
Piciformes	Megalaimidae	*Psilopogon lineatus* (Vieillot, 1816)	Lineated Barbet	R	F	LC
Piciformes	Megalaimidae	*Psilopogon haemacephalus* (Statius Muller, 1776)	Coppersmith Barbet	R	F	LC
Piciformes	Picidae	*Dinopium benghalense* (Linnaeus, 1758)	Black-rumped Flameback	R	I	LC
Piciformes	Picidae	*Leiopicus mahrattensis* (Latham, 1801)	Yellow Crowned Woodpecker	R	I	LC
Psittaciformes	Psittaculidae	*Psittacula eupatria* (Linnaeus, 1766)	Alexandrine Parakeet	R	H	LC
Psittaciformes	Psittaculidae	*Psittacula krameri* (Scopoli, 1769)	Rose-ringed Parakeet	R	H	LC
Psittaciformes	Psittaculidae	*Psittacula cyanocephala* (Linnaeus, 1766)	Plum-headed Parakeet	R	H	LC
Passeriformes	Aegithinidae	*Aegithina tiphia* (Linnaeus, 1758)	Common Lora	R	I	LC
Passeriformes	Alaudidae	*Plocealauda affinis* (Blyth, 1845)	Jerdon's Bushlark	R	I	LC
Passeriformes	Artamidae	*Artamus fuscus* (Vieillot, 1817)	Ashy Woodswallow	R	I	LC
Passeriformes	Campephagidae	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	Small Minivet	R	I	LC
Passeriformes	Campephagidae	*Coracina macei* (Lesson, 1831)	Indian Cuckooshrike	R	I	LC
Passeriformes	Chloropseidae	*Chloropsis jerdoni* (Blyth, 1844)	Jerdon's Leafbird	R	O	LC
Passeriformes	Cisticolidae	*Orthotomus sutorius* (Pennant, 1769)	Common Tailorbird	R	O	LC
Passeriformes	Cisticolidae	*Prinia socialis* (Sykes, 1832))	Ashy Prinia	R	O	LC
Passeriformes	Cisticolidae	*Prinia inornata* (Sykes, 1832)	Plain Prinia	R	O	LC
Passeriformes	Corvidae	*Corvus splendens* (Vieillot, 1817)	House Crow	R	O	LC
Passeriformes	Corvidae	*Dendrocitta vagabunda* (Latham, 1790)	Rufous Treepie	R	O	LC
Passeriformes	Dicruridae	*Dicrurus macrocercus* (Vieillot, 1817)	Black Drongo	R	I	LC
Passeriformes	Estrildidae	*Euodice malabarica* (Linneaus, 1758)	Indian Silverbill	R	O	LC
Passeriformes	Estrildidae	*Lonchura punctulata* (Linnaeus, 1758)	Scaly-breasted Munia	R	G	LC
Passeriformes	Laniidae	*Turdoides striata* (Dumont, 1823)	Jungle Babbler	R	I	LC
Passeriformes	Monarchidae	*Terpsiphone paradisi* (Linnaeus, 1758)	Indian Paradise Flycatcher	WM	C	LC
Passeriformes	Monarchidae	*Hypothymis azurea* (Boddaert, 1783)	Black-naped Monarch	R	I	LC

Order	Family	Scientific name	Common name	Migratory status	Feeding habit	IUCN status
Passeriformes	Muscicapidae	*Copsychus fulicatus* (Linnaeus, 1766)	Indian Robin	R	O	LC
Passeriformes	Muscicapidae	*Ficedula albicilla* (Pallas, 1811)	Taiga Flycatcher	WM	I	LC
Passeriformes	Motacillidae	*Anthus rufulus* (Vieillot, 1818)	Paddyfield Pipit	R	I	LC
Passeriformes	Nectariniidae	*Cinnyris asiaticus* (Latham, 1790)	Purple Sunbird	R	N	LC
Passeriformes	Oriolidae	*Oriolus kundoo* (Sykes, 1832)	Indian Golden Oriole	R	O	LC
Passeriformes	Oriolidae	*Oriolus xanthornus* (Linnaeus, 1758)	Black-hooded Oriole	R	O	LC
Passeriformes	Passeridae	*Passer domesticus* (Linnaeus, 1758)	House Sparrow	R	G	LC
Passeriformes	Phylloscopidae	*Phylloscopus trochiloides* (Sundevall, 1837)	Greenish Warbler	WM	IV	LC
Passeriformes	Pittidae	*Pitta brachyura* (Linnaeus, 1766)	Indian Pitta	R	I	LC
Passeriformes	Pycnonotidae	*Pycnonotus cafer* (Linnaeus, 1766)	Red-vented Bulbul	R	O	LC
Passeriformes	Sturnidae	*Acridotheres ginginianus* (Latham, 1790)	Bank Myna	R	O	LC
Passeriformes	Sturnidae	*Acridotheres tristis* (Linnaeus, 1766)	Common Myna	R	O	LC
Passeriformes	Sturnidae	*Sturnia malabarica* (Gmelin, 1789)	Chestnut-tailed Starling	R	O	LC
Passeriformes	Sturnidae	*Gracupica contra* (Linnaeus, 1758)	Asian Pied Starling	R	O	LC
Passeriformes	Sturnidae	*Sturnia pagodarum* (Gmelin, 1789)	Brahmny Starling	R	O	LC
Passeriformes	Turdidae	*Copsychus saularis* (Linnaeus, 1758)	Oriental Magpie-robin	R	I	LC
Passeriformes	Vangidae	*Tephrodornis pondicerianus* (Gmelin, 1789)	Common Woodshrike	R	O	LC

Species richness and evenness

The Shannon and Simpson's diversity index showed that the post-monsoon season has the richest diversity (H=3.77, D=0.97) but summer (H=3.42, D=0.96), monsoon (H=3.56, D=0.96) and winter (H=3.39, D=0.96) shows similar Simpson's diversity index whereas Shannon's diversity index reveals lowest diversity in the winter season (H=3.39). Although the richness and evenness of the bird species distribution among the seasons are different, the richness is the highest in post-monsoon season, but the evenness is highest in monsoon season. The evenness for winter, summer and post-monsoon seasons is the same whereas the richness in summer, winter and monsoon is very close *(Figure 2)*. The post-monsoon with highest species richness (68 species, J=0.89) followed by monsoon (46 species, J=0.92), summer (45 species, J=0.89) and lastly winter (44 species, J=0.89) *(Figure 3)*.

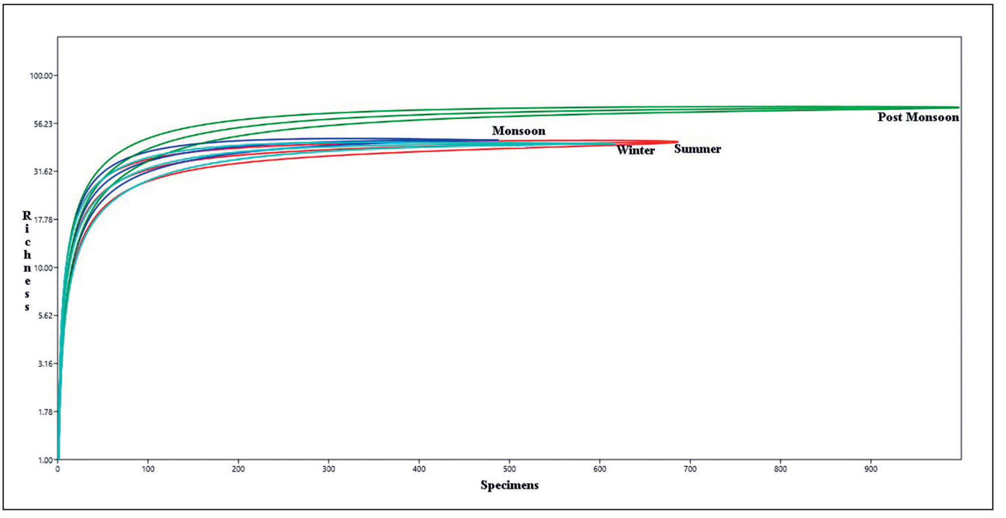

Figure 2. Rarefaction curve of species richness of the birds in Matha Forest in four different seasons
2. ábra A madarak fajgazdagságának ritkasági görbéje a Matha erdőben négy különböző évszakban

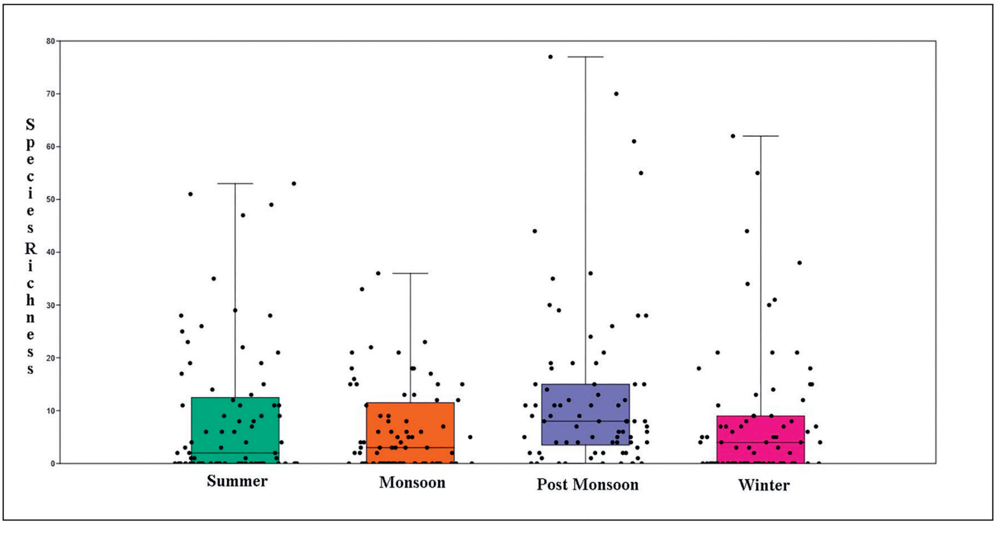

Figure 3. Box jitter plot of bird species richness in four different seasons in Matha Forest, Purulia
3. ábra A Matha erdőben tapasztalt fajgazdagság négy különböző évszakban

The Berger–Parker index for summer and post-monsoon were the same (DBP=0.77) but the dominance of the Asian Palm Swift *(Cypsiurus balasiensis)* was highest in summer whereas Rock Pigeon *(Columba livia)* was the highest in post-monsoon. The Margalef and Menhinick index were also highest for post-monsoon (DMG=9.70, DMN=2.15) but the winter season recorded the lowest value for Margalef index (DMG=6.69) and Menhinick index was the lowest for summer (DMN=1.72) *(Table 2)*.

Table 2. List of various diversity indices calculated based on the distribution of bird species in Matha Forest, Purulia, West Bengal

2. táblázat A különböző diverzitási indexek listája a madárfajok eloszlása alapján a Matha erdőben, Purulia területén, Nyugat-Bengáliában

Index	Summer	Monsoon	Post-Monsoon	Winter
Shannon Diversity Index (H)	3.42	3.56	3.77	3.39
Simpsons Diversity Index (D)	0.96	0.96	0.96	0.95
Evenness index (J’)	0.89	0.92	0.89	0.89
Berger-Parker Index (DBP)	0.07	0.073	0.07	0.10
Margalef Index (DMG)	6.73	7.27	9.70	6.694
Menhinick’s Index (DMN)	1.71	2.08	2.15	1.77

Table 3. Seasonal variation in bird species richness in Matha Forest: One-way ANOVA results. The table presents the results of a one-way ANOVA examining the effect of **season (summer, monsoon, post-monsoon, winter)** on **bird species richness**. The model used was: Values shown include **sum of squares (Sum of sqrs)**, **degrees of freedom (df)**, **mean square (MS)**, **F-statistic (F)**, and **p-value**. The **critical F** value corresponds to p=0.05, p=0.05, p=0.05. A permutation test (n=99,999) was also conducted to validate significance

3. táblázat Az egyszempontú varianciaanalízis (ANOVA) eredményei

	Sum of sqrs	df	Mean square	F	p (same)	Critical F (p=0.05)
Between groups:	1828.32	3	609.442	3.747	0.01143	2.634
Within groups:	49449	304	162.661	Permutation p (n=99999)		
Total:	51277.4	307	0.01128			

“Between groups” refers to variation among seasonal means.
“Within groups” refers to variation within each season.
Total represents the overall variation in richness across all observations.

The one-way ANOVA provided a significant result for the bird richness among the different seasons in Matha Forest (F=3.74, df=3, p=0.01). The NMDS result showed that the variance in bird richness among different seasons have been considerable (non-metric fit, R^2=0.51, Linear fit, R^2=0.34, Stress=0.18) in Bray–Curtis distance calculation *(Table 3, Figure 4).*

Abundance, Density and IVI

The seasonal abundance data *(Figure 5)* reveals the Asian Palm Swift (0.07) was the most abundant in summer whereas Pied Cuckoo *(Clamator jacobinus)*, Greenish Warbler *(Phylloscopus trochiloides)* and Taiga Flycatcher *(Ficedula albicilla)* were the least abundant (0.001). In monsoon, Spotted Dove *(Spilopelia chinensis)* was the most abundant (0.073) whereas Yellow-crowned Woodpecker *(Leiopicus mahrattensis)*, Coppersmith Barbet *(Psilopogon haemacephalus)*, Indian Nightjar *(Caprimulgus asiaticus)* and Indian Peafowl *(Pavo cristatus)* were the least abundant (0.004). In post-monsoon, Rock Pigeon was the most abundant (0.07) whereas Common Hoopoe *(Upupa epops)*, Common Pochard *(Aythya*

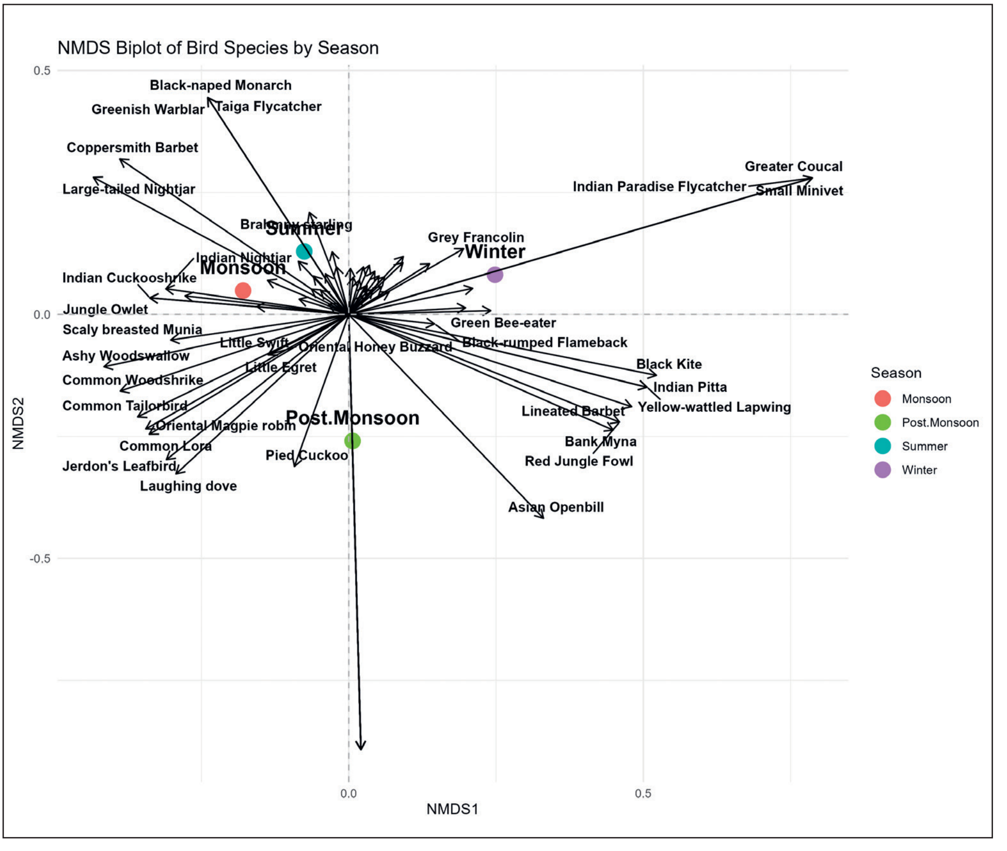

Figure 4. Non-Metric Multi-Dimensional distribution curve of the bird species across the four different seasons in Matha Forest, Purulia

4. ábra A madárfajok nem-metrikus többdimenziós eloszlási görbéje a négy különböző évszakban a Matha erdőben, Puruliában

ferina) and Burred Buttonquail *(Turnix suscitator)* were the least abundant (0.001). Finally in winter, Rock Pigeon abundance was the highest (0.1) followed by Asian Palm Swift (0.08) whereas Asian Openbill *(Anastomus oscitans)* and Indian Pitta *(Pitta brachyura)* were the least abundant (0.003) *(Figure 6)*.

The density of the Rock Pigeon was highest (6.91) followed by Eurasian Collared Dove *(Streptopelia decaocto)* (5.38). The frequency of House Crow *(Corvus splendens)* and Asian Palm Swift represented the maximum (90.63) but the most abundant species was Rock Pigeon (9.61) followed by Spotted Dove (8.05). The Important Value Index describing the relative density, abundance and frequency indicates Rock Pigeon was the highest (15.6) followed by Eurasian Collared Dove (12.75) and Spotted Dove (12.70).

The distribution data of different bird species in different season has revealed the most common species was Common Myna *(Acridotheres tristis)* recorded for all the days surveyed followed by Asian Palm Swift and House Crow for 29 days and Red-vented Bulbul *(Pycnonotus cafer)* for 28 days. The least frequent species which recorded for one day only

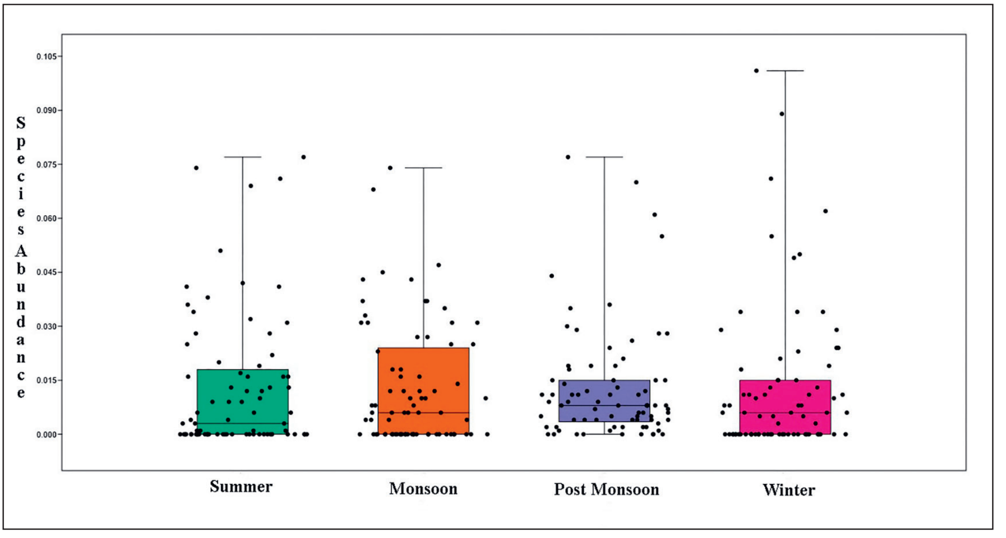

Figure 5. Box jitter plot of bird species abundance in four different seasons in Matha Forest, Purulia
5. ábra A madárfajok tömegessége a négy különböző évszakban a Matha erdőben

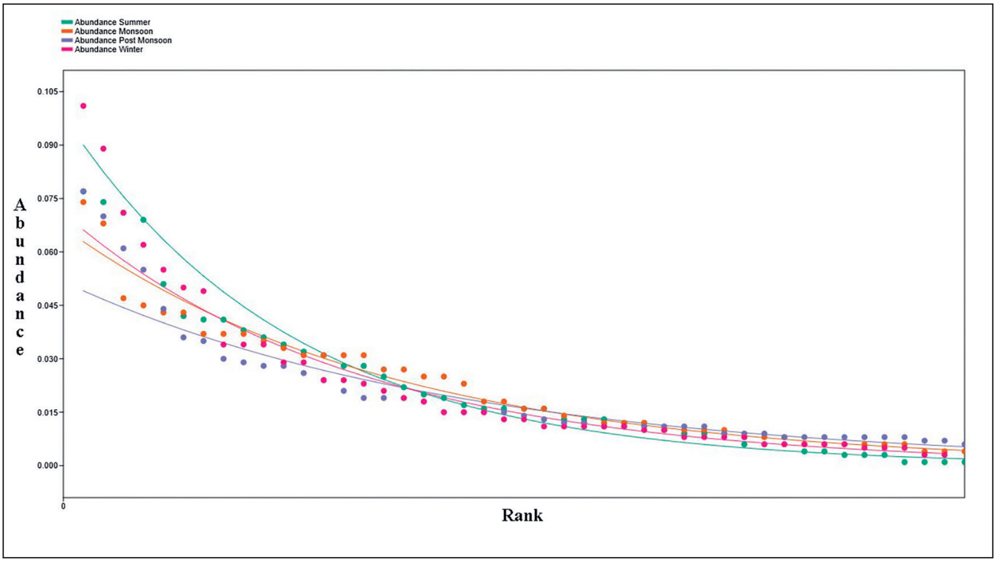

Figure 6. Whittaker plot of bird rank abundance in four different seasons in Matha Forest, Purulia
6. ábra Whittaker-diagram a madárfajok gyakoriságáról négy különböző évszakban a Matha erdőben, Puruliában

were Common Hoopoe, Common Pochard, Black-naped Monarch *(Hypothymis azurea)*, Burred Buttonquail, Jerdon's Bushlark *(Plocealauda affinis)*, Greenish Warbler and Taiga Flycatcher *(Figure 7)*.

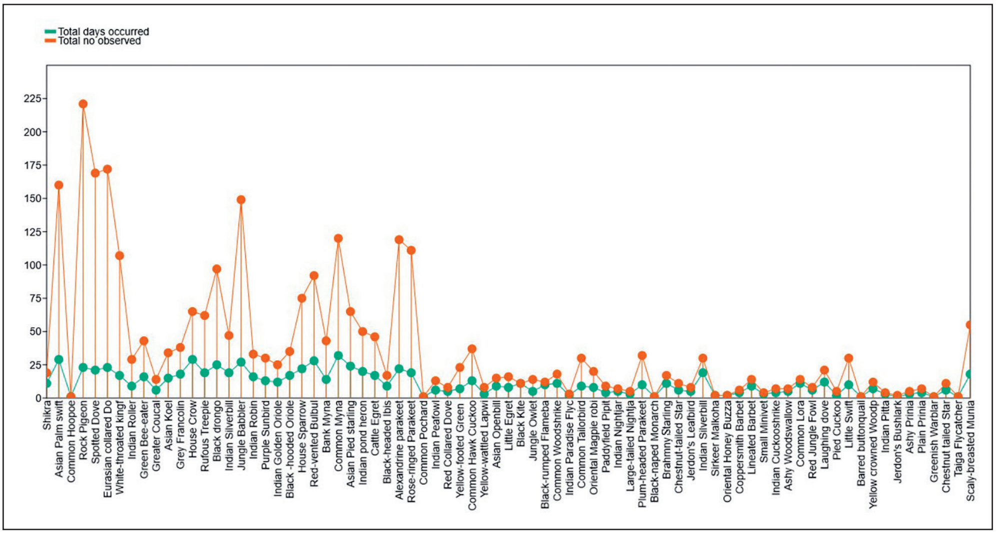

Figure 7. Details of the bird species occurrence in terms of days and total numbers observed in cumulative days in different seasons

7. ábra A különböző évszakokban a napok és az összesített napokon megfigyelt teljes számok alapján megfigyelt fajok előfordulásai

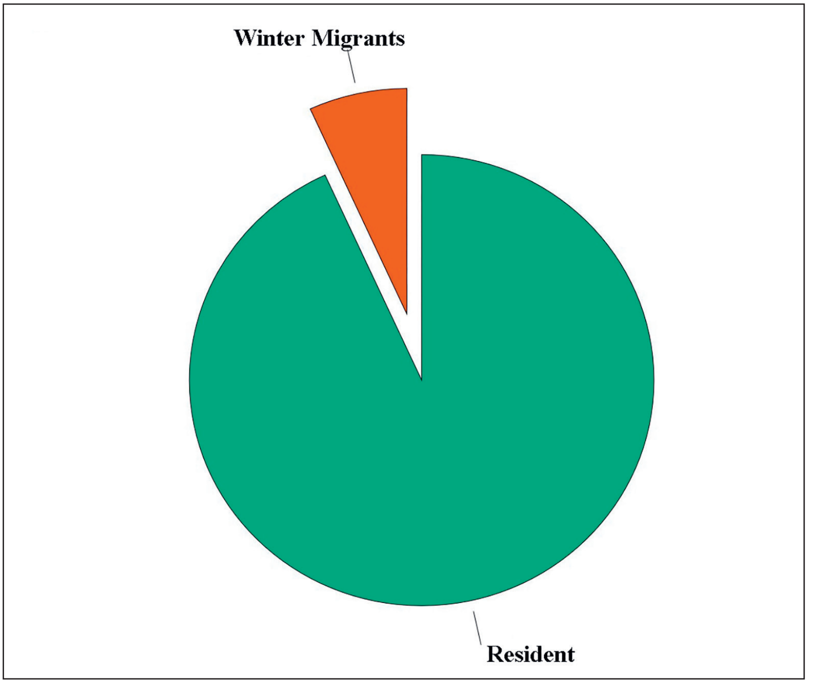

Figure 8. Resident or winter migratory status of the bird species observed in Matha Forest, Purulia in different seasons

8. ábra A Matha erdőben, Puruliában megfigyelt madárfajok rezidens vagy téli vonuló státusza a különböző évszakokban

Feeding guilds

The present study reveal that the resident bird count of the Matha Forest amounts to a total of 2,661 and the winter migrants include 195 individuals which generate the seasonal diversity of the bird species *(Figure 8)*. The feeding behaviour of the birds have been noted, and nine different feeding guilds have been identified. The most abundant feeding habit was omnivorous recorded in the post-monsoon season whereas the least abundant is the insectivorous recorded in the summer. Seasonal distribution of the individuals practicing same feeding habits showed granivorous being the highest, insectivorous being the lowest and no molluscivorous in summer. In monsoon, individuals with omnivorous feeding habit is the highest whereas nectarivores is the lowest with no insectivorous or molluscivorous. Both in post-monsoon and in winter seasons, individuals with omnivorous feeding habits dominates but the insectivorous individual numbers are the lowest in post-monsoon whereas in winter, molluscivorous strategy occurs in the lowest numbers *(Figure 9)*.

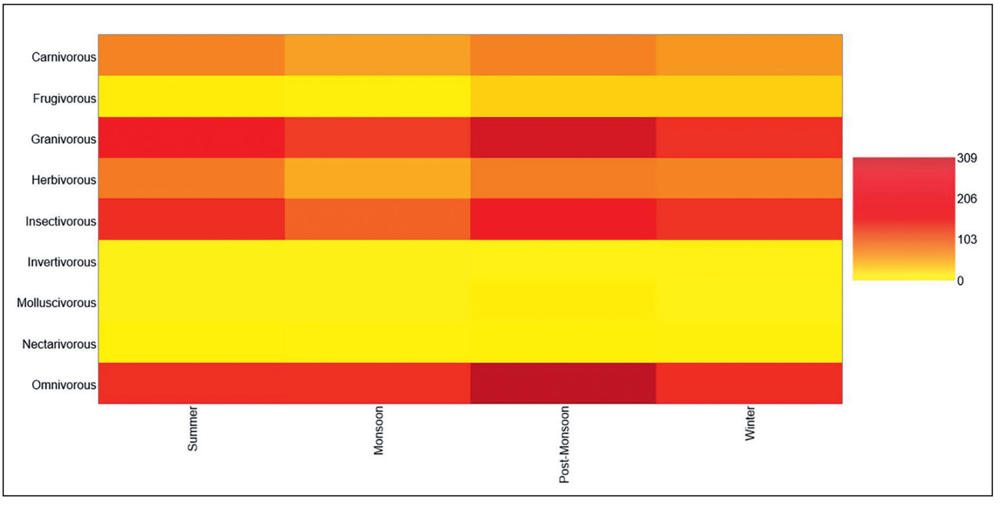

Figure 9. Heatmap of the distribution pattern of various feeding guilds among the bird species observed in different seasons

9. ábra Hőtérkép a különböző évszakokban megfigyelt madárfajok táplálkozási szokásainak eloszlási mintázatáról

Similarity and shared richness

The Euclidean and Jaccard Similarity Indices indicate that summer and winter seasons exhibit greater similarity in species distribution compared to monsoon and post-monsoon, whereas the Bray–Curtis and Morisita indices suggest a closer similarity between monsoon and winter. A total of 27 bird species were found to be common across all four seasons. Notably, all 46 species recorded during the monsoon season were also observed in at least one of the other three seasons. The highest species richness shared between two seasons was observed between monsoon and post-monsoon (43 species), followed by both

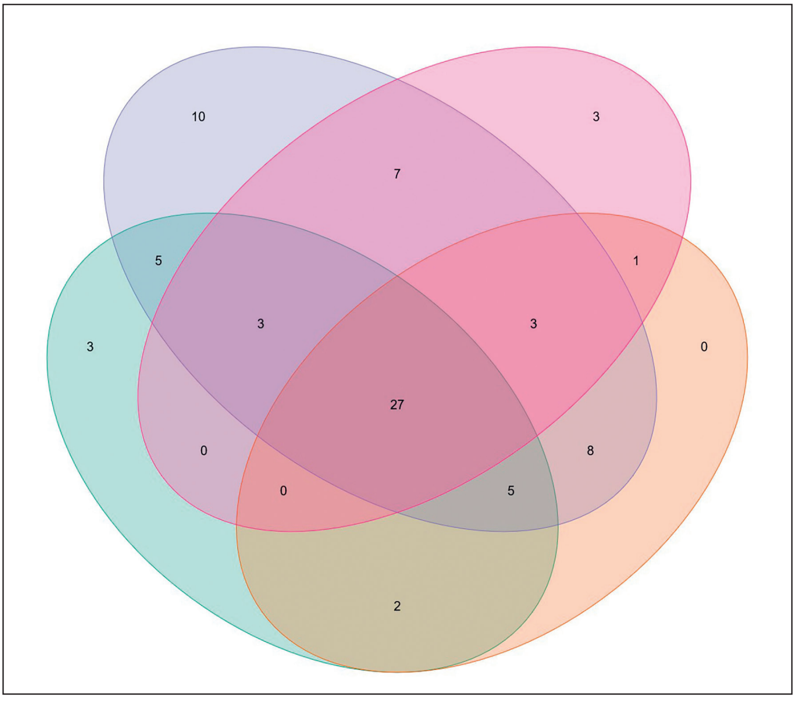

Figure 10. Venn diagram representing the shared and unique number of bird species in different seasons observed in Matha Forest, Purulia

10. ábra A különböző évszakokban megfigyelt madárfajok megosztott és egyedi száma a Matha erdőben a különböző évszakokban

summer–post-monsoon and post-monsoon–summer combinations, each sharing 40 species. The lowest shared richness was recorded between winter and summer, with only 30 species in common *(Figure 10)*.

Discussion

The present study demonstrates that bird species richness in the Matha Forest varies markedly across seasons, peaking during the post-monsoon period. This pattern can be attributed to increased food availability, particularly for granivorous, insectivorous, and omnivorous guilds, which benefit from the post-harvest abundance of grains and higher insect activity. Similar seasonal peaks in bird richness have been observed in tropical and subtropical ecosystems, where food resources and vegetation cover fluctuate with rainfall patterns (Katuwal *et al.* 2016, Castaño-Villa *et al.* 2019). The presence of fledglings following the breeding season (March–June) likely also contributes to the post-monsoon surge, as noted in comparable studies from South Asia (Basnet *et al.* 2019) and Southeast Asia (Sreekar *et al.* 2015).

Despite the presence of migratory species in winter, overall richness declined, likely due to reduced vegetation cover and limited water bodies that constrain habitat diversity. This aligns with observations from other dry tropical forests, where winter assemblages often show lower richness because migratory arrivals do not fully compensate for the decline in resident insectivorous and frugivorous species (Blake & Loiselle 2001, Raman 2006). The relative stability in diversity indices across other seasons suggests that Matha Forest provides a year-round refuge for several adaptable species, particularly those of the Columbidae and Sturnidae families, which thrive in human-modified landscapes. The abundance and dominance of Rock Pigeon, Eurasian Collared Dove, and Spotted Dove indicate the adaptive success of generalist and synanthropic species in fragmented forest–agriculture mosaics. These species often flourish in peri-urban and agricultural environments due to their broad dietary tolerance and nesting adaptability (McKinney 2006, Devictor *et al.* 2007). The high frequency of Common Myna, House Crow, and Asian Palm Swift further reflects the influence of anthropogenic landscapes, echoing findings from other Indian avifaunal studies (Sohil & Sharma 2020, Panda *et al.* 2021). Such patterns suggest that Matha Forest, while still ecologically functional, is undergoing compositional shifts toward species tolerant of disturbance.

From a conservation perspective, these findings are significant. Seasonal shifts in bird communities provide early indicators of ecological change, particularly in fragmented habitats like Matha Forest. The dominance of generalist species and reduced representation of water- and forest-dependent taxa highlight the need for active habitat restoration and protection of microhabitats that support specialist guilds. Strengthening vegetation diversity and preserving natural water sources could help maintain avian heterogeneity across seasons.

The insights from this study can guide local forest management and community-based conservation. Monitoring avian diversity seasonally can serve as a low-cost tool for assessing ecosystem health. The results also emphasize the importance of maintaining mixed forest–agriculture interfaces that balance livelihood needs with biodiversity conservation. This study was limited by its spatial scale and reliance on visual transect surveys, which may underestimate cryptic or nocturnal species. Future research should incorporate automated acoustic monitoring and vegetation structure analysis to better capture habitat–bird relationships. Long-term studies examining the impacts of land-use change, microclimatic variation, and food resource dynamics on bird communities would enhance understanding of the region's ecological resilience.

In conclusion, the study underscores the dynamic nature of avian diversity in the Matha Forest, shaped by seasonal resource availability and anthropogenic influences. By situating these findings within broader ecological contexts, it contributes to the growing body of evidence emphasizing the role of semi-natural habitats in sustaining biodiversity in human-dominated landscapes.

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